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(54) CERAMIC HEATING/COOLING DEVICE

KERAMISCHER APPARAT ZUR ERWAERMUNG UND KUEHLUNG

DISPOSITIF CERAMIQUE DE CHAUFFAGE ET DE REFROIDISSEMENT

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(73) Proprietors:
- KATOH, Keiichi
Kawasaki-shi, Kanagawa-ken 216 (JP)
- UEDA, Syuzi
Tama-shi, Tokyo 206 (JP)

(72) Inventors:
- KATOH, Keiichi
Kawasaki-shi, Kanagawa-ken 216 (JP)
- UEDA, Syuzi
Tama-shi, Tokyo 206 (JP)

(74) Representative: Henkel, Feiler, Hänzel
Möhlstrasse 37
81675 München (DE)

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Description

FIELD OF THE INVENTION

The present invention relates to a heating/cooling apparatus made of a ceramics, which permits a rapid heating and a rapid cooling of various samples in such fields as biotechnology, chemistry, medicine and bioengineering, and achievement of a precise temperature control of the sample and a uniform temperature distribution in the sample.

BACKGROUND OF THE INVENTION

Various types of heating/cooling apparatus have conventionally been employed in the above-mentioned fields for the purpose of rapidly and accurately heating and cooling various samples under a precise temperature control. In a heating/cooling apparatus of any of these types, a receptacle made of a metal such as aluminum or the like for receiving an object to be heated or cooled, i.e., a sample, and a heating means are configured as two separate components. This results in a poorer heat transfer coefficiency from the heating means to the receptacle for the sample, makes it difficult to rapidly heat the sample, and furthermore, leads to a non-uniform temperature distribution in the sample. It is therefore difficult to achieve a desired heating pattern. The available cooling means of the sample include, on the other hand, a spontaneous cooling, a forced cooling with the use of a coolant such as a gas or a liquid, and a combination thereof. It is however difficult to precisely control a cooling rate by such a cooling means alone. It is thus conceivable to control the cooling rate by using any of the above-mentioned cooling means while supplying a prescribed heat quantity from the heating means to the sample. In this manner of cooling, however, the heat supplied by the heating means cannot be efficiently transferred to the receptacle for the sample. It is therefore difficult to rapidly decrease the sample temperature to a desired temperature, and moreover, the temperature distribution in the sample is non-uniform, resulting in difficulty in achieving a desired cooling pattern.

An object of the present invention is therefore to provide a heating/cooling apparatus made of a ceramics, which solves the above-mentioned problems, and permits a rapid heating and a rapid cooling of various samples, allows a precise temperature control of the sample, thereby enabling a temperature control of the sample in accordance with a predetermined temperature pattern, and achieving a uniform temperature distribution in the sample.

DISCLOSURE OF THE INVENTION

According to the present invention there is provided a heating/cooling apparatus made of ceramics as defined in claims 1 and 6.

In the heating/cooling apparatus made of a ceramics of the present invention, at least one of a face, at least one hole, at least one recess and at least one groove, the shape of which coincides with that of an object to be heated or cooled, i.e., a sample, for receiving the sample, to increase a contact area with the sample, is formed at an arbitrary position on a sintered body comprising an electrically insulating ceramics having a thermal conductivity of at least 10 W/(m · k). An electrically conductive resistance-heating element comprising a metal, an electrically conductive ceramics or carbon is buried into the sintered body. In the heating/cooling apparatus made of a ceramics of the present invention, the whole of the above-mentioned sintered body may comprise an electrically conductive ceramics, thereby the sintered body itself forming a resistance-heating element as a heating means.

The heating/cooling apparatus made of a ceramics of the present invention further comprises a cooling means. The cooling means comprises a coolant feeder, provided outside the sintered body, for feeding a coolant such as a gas or a liquid to the sintered body, on the one hand, and at least one of part of a surface of the sintered body, a rugged portion formed on part of a surface of the sintered body, at least one cooling through-hole, through which the coolant passes, formed in the sintered body, a heat-radiating plate having fins, provided on the sintered body, and a heat-radiating plate having a honeycomb structure, provided on the sintered body, each for effecting a heat exchange, on the other hand. The heat-radiating plate comprises any one of a metal and a ceramics.

According to the heating/cooling apparatus made of a ceramics having the construction as described above, the sample is in contact with the face, at least one hole, at least one recess or at least one groove, each for receiving the sample, provided on the sintered body having a satisfactory thermal conductivity, so that the temperature of the sample rapidly becomes equal to the temperature of the sintered body, thus permitting a precise temperature control during the heating and the cooling of the sample.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a first embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride.

Fig. 2 is a schematic sectional view of Fig. 1 cut along the line A-A'.

Fig. 3 is a schematic exploded perspective view illustrating a manufacturing process of the heating/cooling apparatus made of a ceramics of the first embodiment of the present invention shown in Fig. 1.

Fig. 4 is a schematic descriptive view illustrating a

combination of the heating/cooling apparatus made of a ceramics of the first embodiment of the present invention shown in Fig. 1, and a coolant feeder.

Fig. 5 is a graph illustrating a predetermined temperature pattern in a performance test of a heating/cooling apparatus made of a ceramics.

Fig. 6 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a second embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride.

Fig. 7 is a schematic sectional view of Fig. 6 cut along the line A-A'.

Fig. 8 is a schematic perspective view illustrating two green blocks for the heating/cooling apparatus made of a ceramics of the second embodiment of the present invention shown in Fig. 6.

Fig. 9 is a schematic perspective view illustrating the state in which a resistance-heating element is attached onto one of the two green blocks shown in Fig. 8.

Fig. 10 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a third embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride, and a heat-radiating plate having fins, as a cooling means.

Fig. 11 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a fourth embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride, and at least one cooling through-hole as a cooling means, formed in the sintered body.

Fig. 12 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a fifth embodiment of the present invention, which comprises a sintered body made of a ceramics comprising silicon carbide.

Fig. 13 is a schematic perspective view illustrating a green block for the heating/cooling apparatus made of a ceramics of the fifth embodiment of the present invention shown in Fig. 12.

Fig. 14 is a schematic perspective view illustrating a green block having holes formed therein for receiving objects to be heated or cooled, i.e., samples, for the heating/cooling apparatus made of a ceramics of the fifth embodiment of the present invention shown in Fig. 12.

Fig. 15 is a schematic descriptive view illustrating a combination of the heating/cooling apparatus made of a ceramics of the fifth embodiment of the present invention shown in Fig. 12, and a coolant feeder.

Fig. 16 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a sixth embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride, provided with at least one peephole.

Fig. 17 is a schematic sectional view of Fig. 16 cut along the line A-A'.

Fig. 18 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a seventh embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride.

Fig. 19 is a schematic sectional view of Fig. 18 cut along the line A-A'.

Fig. 20 is a schematic sectional view of Fig. 18 cut along the line B-B', illustrating the heating/cooling apparatus made of a ceramics of the seventh embodiment of the present invention shown in Fig. 18, which is attached with a sample receptacle.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, the heating/cooling apparatus made of a ceramics of the present invention is described further in detail with reference to the drawings.

Fig. 1 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a first embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride, and Fig. 2 is a schematic sectional view of Fig. 1 cut along the line A-A'. The heating/cooling apparatus made of a ceramics of the first embodiment of the present invention is manufactured as follows. As shown in Fig. 3, holes 2 and 3 for receiving samples are formed in each of green sheets 7, 8 and 10 made of a ceramics comprising aluminum nitride. With the use of a paste prepared by kneading at least one powdery raw material selected from the group consisting of tungsten, molybdenum and rhenium, a resistance-heating element 5 is formed on the surface of the green sheet 8 by a method such as a screen printing. Then, the green sheets 7, 8 and 10 are piled one upon another, and a sintered body 1 is formed by sintering these green sheets 7, 8 and 10 thus piled up. The sintered body 1 thus formed has a shape as shown in Fig. 1, and the side surfaces opposite to each other have electrodes 4 and 4', respectively, connected to the resistance-heating element 5.

Then, a performance test was carried out by using the heating/cooling apparatus made of a ceramics prepared as described above. Fig. 4 is a schematic descriptive view illustrating a combination of the above-mentioned heating/cooling apparatus of the first embodiment of the present invention, and a coolant feeder. When heating a sample, voltage was impressed on the electrodes 4 and 4'. When cooling the sample, a cooling gas was supplied to the heating/cooling apparatus by means of a blower 11 as the coolant feeder. Each of test tubes having a thermocouple received therein was inserted into each of the holes 2 and 3 to investigate the performance of the heating/cooling apparatus. Temperature of each test tube was subjected to a PID (abbreviation of proportional-plus-integral-plus-derivative) control on the basis of the temperature measured by the thermocouple, so that the temperature of the test tube

coincided with a target temperature. Electric power of the resistance-heating element 5 was controlled with the use of a thyristor.

The performance test was carried out as follows. Two test tubes filled with objects to be heated or cooled, i.e., samples, were inserted respectively into the holes 2 and 3 for receiving samples of the heating/cooling apparatus, and the samples were heated or cooled with the use of the above-mentioned heating/cooling apparatus in accordance with a predetermined temperature pattern as shown in Fig. 5, thereby precisely controlling the temperature of the samples. More specifically, the test tubes each receiving 1.5 $m\ell$ of pure water were inserted respectively into the holes 2 and 3, each having an inside diameter agreeing with the outside diameter of the test tubes, of the heating/cooling apparatus shown in Fig. 1. A thermocouple for measuring temperature was immersed into the middle of pure water received in each of the test tubes. Pure water in each of the two test tubes showed an initial temperature of 17 °C, as measured by the thermocouple.

Subsequently, a program regarding set temperatures and set periods for heating and cooling pure water, was input into a controller for controlling the operation of the heating/cooling apparatus. The above-mentioned program comprised, as shown in Fig. 5: increasing the temperature of pure water to 95°C (hereinafter referred to as the "first set temperature"), then keeping this temperature for ten minutes (hereinafter referred to as the "first set period"), then decreasing the temperature of pure water to 4°C (hereinafter referred to as the "second set temperature"), then keeping this temperature for 60 minutes (hereinafter referred to as the "second set period"), then increasing again the temperature of pure water to 25°C (hereinafter referred to as the "third set temperature"), then keeping this temperature for 20 minutes (hereinafter referred to as the "third set period"), and then discontinuing the operation of the heating/cooling apparatus.

Then, the heating/cooling apparatus was operated under the control by means of the controller, and actual changes in temperature with time of pure water received in each of the two test tubes, were measured by the thermocouple. The results of measurement were as follows. Upon the lapse of eight seconds after the start of operation of the heating/cooling apparatus, the temperature of pure water in each of the test tubes increased to 95 °C which was the first set temperature. Thereafter, during ten minutes which were the first set period, the temperature of pure water in each of the test tubes was kept at a temperature of 95 ± 0.1°C. Then, upon the lapse of 20 seconds after the first set period, the temperature of pure water in each of the test tubes decreased to 4°C which was the second set temperature. Then, during 60 minutes which were the second set period, the temperature of pure water in each of the test tubes was kept at a temperature of 4 ± 0.1°C. Subsequently, upon the lapse of two seconds after the second set period, the temperature of pure water in each of the test tubes increased to 25°C which was the third set temperature. Then, during 20 minutes which were the third set period, the temperature of pure water in each of the test tubes was kept at a temperature of 25 ± 0.1°C, and thereafter, the operation of the heating/cooling apparatus was discontinued.

The sintered body 1 of the heating/cooling apparatus made of a ceramics of the above-mentioned first embodiment of the present invention, has been described above as comprising an electrically insulating ceramics comprising aluminum nitride. The sintered body 1 may however comprise an electrically insulating ceramics comprising at least one of silicon carbide, silicon nitride, aluminum oxide and beryllium oxide, other than aluminum nitride. The material for forming the resistance-heating element 5 is not limited to at least one metal selected from the group consisting of tungsten, molybdenum and rhenium, but may be carbon, and furthermore, may be at least one electrically conductive ceramics selected from the group consisting of silicon carbide, titanium nitride, molybdenum silicide, zirconium boride, tungsten carbide and tantalum carbide. In addition, in the heating/cooling apparatus made of the ceramics of the above-mentioned first embodiment of the present invention, the resistance-heating element 5 is buried in the form of a single layer into the sintered body 1. However, a resistance-heating element comprising a plurality of layers may be buried into the sintered body 1. In the heating/cooling apparatus of the above-mentioned first embodiment of the present invention, the holes 2 and 3 for receiving the samples may have any shape in any number.

Fig. 6 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a second embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride, and Fig. 7 is a schematic sectional view of Fig. 6 cut along the line A-A'. The heating-cooling apparatus made of a ceramics of the second embodiment of the present invention is manufactured as follows. A powdery raw material comprising aluminum nitride is charged into a metallic mold not shown to form two green blocks 21 and 22 as shown in Fig. 8. Then, resistance-heating elements 19 and 20 each comprising a coiled wire made of at least one metal selected from the group consisting of tungsten, molybdenum and rhenium, are arranged on the surface of the green block 22 as shown in Fig. 9. Then, the other green block 21 is placed upon the green block 22, and as shown in Figs. 6 and 7, holes 13, 14, 15 and 16 for receiving samples are formed by means of a cutting. Thereafter, the two green blocks thus provided with the holes are sintered by a hot press method, thereby preparing a sintered body 12 made of a ceramics comprising aluminum nitride having the resistance-heating elements 19 and 20 buried therein. Then, the side surfaces of the sintered body 12 are ground to expose ends of the coiled wires

as the resistance-heating elements 19 and 20. Then, electrodes 17 and 18 are brazed onto the ends of the coiled wires thus exposed.

A performance test of the heating/cooling apparatus made of a ceramics of the above-mentioned second embodiment of the present invention was carried out in the same manner as in that of the heating/cooling apparatus made of the ceramics of the first embodiment of the present invention. As in the performance test of the heating/cooling apparatus of the first embodiment of the present invention, a blower as a coolant feeder was arranged below the heating/cooling apparatus, thereby blowing a cooling gas toward the heating-cooling apparatus to cool same. The temperature of the sample was controlled also in the same manner as in the performance test of the heating/cooling apparatus of the first embodiment of the present invention. Also in the performance test of the heating/cooling apparatus of the second embodiment of the present invention, there were obtained excellent results of the performance test as in the heating/cooling apparatus of the first embodiment of the present invention. Furthermore, the heating/cooling apparatus of the second embodiment of the present invention was improved by providing a rugged portion or fins by means of a grinding on part of the surface of the sintered body 12, and the same performance test as described above was carried out for each of such improvements. There were obtained excellent results of the performance test as in the heating/cooling apparatus of the second embodiment of the present invention. Particularly within a range of temperature of from 100 to 600°C, there was available a cooling rate higher than that in the heating/cooling apparatus of the first embodiment of the present invention. In the heating/cooling apparatus of the second embodiment of the present invention, the holes 13, 14, 15 and 16 for receiving samples may be of any shape in any number, and the resistance-heating elements 19 and 20 may be in any number.

Fig. 10 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a third embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride, and a heat-radiating plate having fins, as a cooling means. The heating/cooling apparatus of the third embodiment of the present invention is configured by forming a metallic layer comprising at least one metal of copper, nickel, molybdenum and manganese on the lower surface of the heating/cooling apparatus of the above-mentioned second embodiment of the present invention, and then brazing a metallic heat-radiating plate 30 having fins, as a cooling means, onto the metallic layer. In Fig. 10, 23 is a sintered body; 24, 25, 26 and 27 are holes for receiving samples; and 28 and 29 are electrodes.

A performance test of the heating/cooling apparatus made of a ceramics of the above-mentioned third embodiment of the present invention was carried out in the same manner as in that of the heating/cooling apparatus made of a ceramics of the first embodiment of the present invention. Also in the performance test of the heating/cooling apparatus of the third embodiment of the present invention, there were obtained excellent results of the performance test as in the heating/cooling apparatus of the first embodiment of the present invention. Particularly within a range of temperature of from 100 to 600°C, there was available a cooling rate higher than that of the heating/cooling apparatus of the first embodiment of the present invention. In the heating/cooling apparatus of the third embodiment of the present invention, the metallic heat-radiating plate 30 having fins, as a cooling means, has been described as being provided on the lower surface of the sintered body 23. However, the above-mentioned heat-radiating plate 30 may be provided on a surface other than the lower surface of the sintered body 23, for example, on a side surface thereof. Furthermore, the above-mentioned heat-radiating plate 30 may have a honeycomb structure in place of the fins.

Fig. 11 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a fourth embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride, and at least one cooling through-hole as a cooling means, formed in the sintered body. The heating/cooling apparatus of the fourth embodiment of the present invention is configured by forming cooling through-holes 38 and 39 as cooling means, as shown in Fig. 11, by means of an ultrasonic working, a diamond grinding or the like, in the sintered body of the heating/cooling apparatus of the second embodiment of the present invention. In Fig. 11, 31 is a sintered body; 32, 33, 34 and 35 are holes for receiving samples; and 36 and 37 are electrodes. When cooling samples with the use of the heating/cooling apparatus of the fourth embodiment of the present invention, a cooling gas is supplied into the cooling through-holes 38 and 39.

A performance test of the heating/cooling apparatus made of a ceramics of the above-mentioned fourth embodiment of the present invention was carried out in the same manner as in that of the heating/cooling apparatus made of a ceramics of the first embodiment of the present invention. Also in the performance test of the heating/cooling apparatus of the fourth embodiment of the present invention, there were obtained excellent results of the performance test as in the heating/cooling apparatus of the first embodiment of the present invention. Particularly within a range of temperature of from 100 to 600 °C, there was available a cooling rate higher than that of the heating/cooling apparatus of the first embodiment of the present invention. In the performance test of the heating/cooling apparatus of the fourth embodiment of the present invention, a cooling gas has been described as being supplied into the cooling through-holes 38 and 39 as the cooling means. However, a liquid coolant may be supplied into the cooling through-holes 38 and 39. A partition having a honey-

comb structure may be provided as required in each of the cooling through-holes 38 and 39.

Fig. 12 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a fifth embodiment of the present invention, which comprises a sintered body made of a ceramics comprising silicon carbide. In Fig. 12, 40 is a sintered body made of an electrically conductive ceramics comprising silicon carbide; and 41 and 42 are holes for receiving samples. The heating/cooling apparatus made of a ceramics of the fifth embodiment of the present invention is manufactured as follows. A powdery raw material comprising an electrically conductive ceramics comprising silicon carbide is charged into a metallic mold not shown to form a green block 45 as shown in Fig. 13. Then, as shown in Fig. 14, holes 41 and 42 for receiving samples are formed in the green block 45 by means of a cutting. Subsequently, the green block 45 thus provided with the holes 41 and 42 is sintered under the known sintering conditions. Then, metallic layers as electrodes 43 and 44 are attached, as shown in Fig. 12, onto the opposing side surfaces of the resultant sintered body 40, respectively. In the heating/cooling apparatus of the fifth embodiment of the present invention, the sintered body 40 itself forms a resistance-heating element serving as a heating means. There is no need therefore to specifically provide resistance-heating element in the sintered body 40.

A performance test of the heating/cooling apparatus made of a ceramics of the above-mentioned fifth embodiment of the present invention was carried out in the same manner as in that of the heating/cooling apparatus made of a ceramics of the first embodiment of the present invention. As in the performance test of the heating/cooling apparatus of the first embodiment of the present invention, a blower 50 as a coolant feeder was arranged, as shown in Fig. 15, below the heating/cooling apparatus, thereby blowing a cooling gas toward the heating/cooling apparatus to cooling same. Also in the performance test of the heating/cooling apparatus of the fifth embodiment of the present invention, there were obtained excellent results of the performance test as in the heating/cooling apparatus of the first embodiment of the present invention.

The sintered body 40 of the heating/cooling apparatus of the fifth embodiment of the present invention has been described above as comprising an electrically conductive ceramics comprising silicon carbide, but the sintered body 40 may comprise any one electrically conductive ceramics selected from the group consisting of titanium nitride, a mixture of aluminum nitride and carbon and a mixture of silicon nitride and molybdenum silicide, other than silicon carbide. The heating/cooling apparatus of the fifth embodiment of the present invention has been described above as having the two holes 41 and 42 for receiving samples. It is not however limited to this structure, but the holes may be of any shape in any number. It is also possible, as required, to provide the sintered body 40 with a heat-radiating plate having fins, a heat-radiating plate having a honeycomb structure, or at least one cooling through-hole, as a cooling means.

Fig. 16 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramics of a sixth embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride, provided with at least one peephole. In Fig. 16, 51 is a sintered body; 52 and 53 are holes for receiving samples; 54 is an electrode; 55 and 56 are peepholes for visually or optically observing samples in test tubes, for example; and 57, 58 and 59 are cooling through-holes, as cooling means, through which a coolant passes. Fig. 17 is a schematic sectional view of Fig. 16 cut along the line A-A'. In Fig. 17, 63 is a resistance-heating element. According to the heating/cooling apparatus of the sixth embodiment of the present invention, it is possible to observe, through the peepholes 55 and 56, the state of samples while appropriately controlling the temperature of the samples. The peepholes 55 and 56 may be of any shape in any number. It is possible to form optical paths for observation by filling the peepholes 55 and 56 with any one of an optically permeable ceramics, an optically permeable glass and an optically permeable resin. In the heating/cooling apparatus of the sixth embodiment of the present invention, there is used a combination of: (1) any one of the several kinds of the chemical composition of the sintered body, and (2) any one of the several kinds of the chemical composition of the resistance-heating element, as described above in relation to the above-mentioned first to fifth embodiments of the present invention. The holes 52 and 53 for receiving samples may be of any shape in any number.

Fig. 18 is a schematic perspective view illustrating a heating/cooling apparatus made of a ceramic of a seventh embodiment of the present invention, which comprises a sintered body made of a ceramics comprising aluminum nitride. In Fig. 18, 60 is a sintered body made of a ceramics comprising aluminum nitride; 61 is an electrode; and 62 are a plurality of cooling through-holes as cooling means, through which a coolant passes. Fig. 19 is a schematic sectional view of Fig. 18 cut along the line A-A'. In Fig. 19, 66 is a resistance-heating element comprising tungsten, connected to the electrode 61. Fig. 20 is a schematic sectional view of Fig. 18 cut along the line B-B', illustrating the heating/cooling apparatus of the seventh embodiment of the present invention shown in Fig. 18, which is attached with a sample receptacle 64. In Fig. 20, 65 are a plurality of recesses for samples; and 62 is a cooling through-hole as a cooling means.

A performance test of the heating/cooling apparatus made of a ceramics of the above-mentioned seventh embodiment of the present invention was carried out in the same manner as in that of the heating/cooling apparatus made of a ceramics of the first embodiment of the present invention. Pure water identical with that in the performance test of the heating/cooling apparatus

of the first embodiment of the present invention, was poured into each of the recesses for samples 65. Also in the performance test of the heating/cooling apparatus of the seventh embodiment of the present invention, there was employed the same temperature controlling method as that in the performance test of the heating/cooling apparatus of the first embodiment of the present invention. More specifically, the control of temperature was effected on the basis of the temperatures of pure water measured by means of the thermocouple immersed into pure water received in each of the recesses for samples 65. Satisfactory results of the performance test were obtained in the performance test of the heating/cooling apparatus of the seventh embodiment of the present invention. An error between the temperature of pure water in each of the recesses for samples 65 and the target temperature was within ± 1°C. In the heating/cooling apparatus of the seventh embodiment of the present invention, there may be used a combination of: (1) any one of the several kinds of the chemical composition of the sintered body, (2) any one of the several kinds of the chemical composition of the resistance-heating element, and (3) any one of the several kinds of the cooling means, as described above in relation to the above-mentioned first to fifth embodiments of the present invention.

INDUSTRIAL APPLICABILITY

According to the heating/cooling apparatus made of a ceramics of the present invention, as described above in detail, it is possible to rapidly heat and cool various samples, to precisely control the temperature of the sample, to keep a uniform temperature distribution in the sample, and to conduct a precise temperature control in accordance with a predetermined complicated temperature program, which was impossible by any of the conventional technologies, thus providing useful effects in such fields as biotechnology, chemistry, medicine and bioengineering, and providing industrially useful effects.

Claims

1. A heating/cooling apparatus made of a ceramics, which comprises:
   a sintered body (1;12;23;31;51;60) having at least one of :

   a face, at least one hole (2,3;13-16;24-27;32-35;52,53), at least one recess (65) and at least one groove, each for receiving an object to be heated or cooled, said sintered body (1;12;23;31;51;60) comprising an electrically insulating ceramics having a thermal conductivity of at least 10 W/(m•k) ;
   at least one resistance-heating element (5;19,20;63) serving as a heating means, which is buried into said sintered body (1;12;23;31;51;60); and
   a cooling means comprising a coolant feeder (11;50), provided outside said sintered body (1;12;23;31;51;60), for feeding a coolant to said sintered body, and at least one of: part of a surface of said sintered body, a rugged portion formed on part of a surface of said sintered body, at least one cooling through-hole (38,39;57-59;62), through which said coolant passes, formed in said sintered body, a heat-radiating plate (30) having fins, provided on said sintered body, and a heat-radiating plate having a honeycomb structure, provided on said sintered body, each for effecting a heat exchange with said fed coolant.

2. A heating/cooling apparatus made of a ceramics as claimed in claim 1, wherein:

   said sintered body (1;12;23;31;51;60) comprises said electrically insulating ceramics comprising at least one selected from the group consisting of aluminum nitride, silicon carbide, silicon nitride, aluminum oxide and beryllium oxide.

3. A heating/cooling apparatus made of a ceramics as claimed in claim 1 or 2, wherein:

   said resistance-heating element (5;19,20;63) comprises any one of a metal, an electrically conductive ceramics and carbon.

4. A heating/cooling apparatus made of a ceramics as claimed in claim 3, wherein:

   said resistance-heating element comprises at least one metal selected from the group consisting of tungsten, molybdenum and rhenium.

5. A heating/cooling apparatus made of a ceramics as claimed in claim 3, wherein:

   said resistance-heating element comprises at least one electrically conductive ceramics selected from the group consisting of silicon carbide, titanium nitride, molybdenum silicide, zirconium boride, tungsten carbide and tantalum carbide.

6. A heating/cooling apparatus made of a ceramics, which comprises:
   a sintered body (40) having at least one of :

   a face, at least one hole (41,42), at least one recess and at least one groove, each for receiv-

ing an object to be heated or cooled, the whole of said sintered body (40) comprising an electrically conductive ceramics, thereby said sintered body (40) itself forming a resistance-heating element serving as a heating means; and
a cooling means comprising a coolant feeder (11;50) provided outside said sintered body (40), for feeding a coolant to said sintered body, and at least one of : part of a surface of said sintered body, a rugged portion formed on part of a surface of said sintered body, at least one cooling through-hole (38,39;57-59;62), through which said coolant passes, formed in said sintered body, a heat-radiating plate (30) having fins, provided on said sintered body, and a heat-radiating plate having a honeycomb structure, provided on said sintered body, each for effecting a heat exchange with the fed coolant.

7. A heating/cooling apparatus made of a ceramics as claimed in claim 6, wherein:

   said sintered body (40) comprises any one electrically conductive ceramics selected from the group consisting of silicon carbide, titanium nitride, a mixture of aluminum nitride and carbon and a mixture of silicon nitride and molybdenum silicide.

8. A heating/cooling apparatus made of a ceramics as claimed in any one of the claims 1 to 7, wherein:

   said heat-radiating plate comprises any one of a metal and a ceramics.

9. A heating/cooling apparatus made of a ceramics as claimed in any one of claims 1 to 7, wherein:

   said at least one cooling through-hole comprises a plurality of through-holes (57,58,59), and each of said plurality of through-holes has a honeycomb structure.

10. A heating/cooling apparatus made of a ceramics as claimed in any one of the preceding claims, wherein:

   at least one peephole (55,56) for observing said object to be heated or cooled, which communicates with said at least one hole, said at least one recess or said at least one groove of said sintered body (1;12;23;31;40;51;60), for receiving said object to be heated or cooled, is formed in said sinted body (1;12;23;31;40;51;60).

11. A heating/cooling apparatus made of a ceramics as claimed in claim 10, wherein:

   said at least one peephole (55,56) is filled with any one of an optically permeable ceramics, an optically permeable glass and an optically permeable resin.

Patentansprüche

1. Erwärmungs-/Kühlvorrichtung aus Keramik, umfassend:

   einen Sinterkörper (1;12;23;31;51;60) mit mindestens jeweils einer Fläche, mindestens einem Loch (2;3;13-16;24-27;32-35;52,53), mindestens einer Ausnehmung (65) und bzw.mindestens einer Nut bzw. Rille, jede(s) jeweils zur Aufnahme eines zu erwärmenden oder zu kühlenden Gegenstands, wobei der Sinterkörper (1;12;23;31;51;60) aus einem elektrisch isolierenden Keramikmaterial mit einem Wärmeleitwert von mindestens 10 W/(m·k) besteht,
   mindestens ein als Erwärmungseinrichtung dienendes Widerstandsheizelement (5;19,20;63), das in den Sinterkörper (1;12;23;31;51;60) eingebettet ist, sowie
   eine Kühleinrichtung mit einer außerhalb des Sinterkörpers (1;12;23;31;51;60) vorgesehenen Kühlmittelzuführung (11;50) zum Zuführen eines Kühlmittels zu dem Sinterkörper, sowie mit mindestens jeweils einem Teil einer Oberfläche des Sinterkörpers, einem auf einem Teil einer Oberfläche des Sinterkörpers gebildeten, aufgerauhten Abschnitt, mindestens einem in dem Sinterkörper ausgebildeten Kühlungs-Durchgangsloch (38,39;57-59;62), welches das Kühlmittel passiert, einer an dem Sinterkörper vorgesehenen, Wärme abstrahlenden Platte (30) mit Stegen bzw. Rippen, sowie (bzw.) einer an dem Sinterkörper vorgesehenen, Wärme abstrahlenden Platte mit einer Wabenstruktur, jeweils zum Bewirken eines Wärmeaustausches mit dem zugeführten Kühlmittel.

2. Erwärmungs-/Kühlvorrichtung aus Keramik nach Anspruch 1, wobei

   der Sinterkörper (1;12;23;31;51;60) das elektrisch isolierende Keramikmaterial umfaßt, welches mindestens einen aus der aus Aluminiumnitrid, Siliziumkarbid, Siliziumnitrid, Aluminiumoxid und Berylliumoxid bestehenden Gruppe ausgewählten Stoff aufweist.

3. Erwärmungs-/Kühlvorrichtung aus Keramik nach Anspruch 1 oder 2, wobei

   das Widerstandsheizelement (5;19,20;63) aus einem Metall, einem elektrisch leitfähigen Ke-

ramikmaterial oder Kohlenstoff besteht.

4. Erwärmungs-/Kühlvorrichtung aus Keramik nach Anspruch 3, wobei

   das Widerstandsheizelement mindestens ein aus der aus Wolfram, Molybdän und Rhenium bestehenden Gruppe ausgewähltes Metall aufweist.

5. Erwärmungs-/Kühlvorrichtung aus Keramik nach Anspruch 3, wobei

   das Widerstandsheizelement mindestens ein aus der aus Siliziumkarbid, Titannitrid, Molybdänsilicid, Zirkonborid, Wolframkarbid und Tantalkarbid bestehenden Gruppe ausgewähltes, elektrisch leitfähiges Keramikmaterial aufweist.

6. Erwärmungs-/Kühlvorrichtung aus Keramik, die umfaßt:

   einen Sinterkörper (40) mit mindestens jeweilseiner Fläche, mindestens einem Loch (41,42), mindestens einer Ausnehmung und (bzw.) mindestens einer Nut bzw. Rille, jeweils zur Aufnahme eines zu erwärmenden oder zu kühlenden Gegenstands, wobei der gesamte Sinterkörper (40) ein elektrisch leitendes Keramikmaterial aufweist, wodurch der Sinterkörper (40) selbst ein Widerstandsheizelement bildet, das als Erwärmungseinrichtung dient, und
   eine Kühleinrichtung mit einer außerhalb des Sinterkörpers (40) vorgesehenen Kühlmittelzufuhr (11;50) zum Zuführen eines Kühlmittels zu dem Sinterkörper, sowie mit mindestens jeweils einem Teil einer Oberfläche des Sinterkörpers, einem auf einem Teil einer Oberfläche des Sinterkörpers gebildeten, aufgerauhten Abschnitt, mindestens einem in dem Sinterkörper ausgebildeten Kühlungs-Durchgangsloch (38,39;57-59;62), welches das Kühlmittel passiert, einer an dem Sinterkörper vorgesehenen, Wärme abstrahlenden Platte (30) mit Stegen bzw. Rippen sowie (bzw.) einer an dem Sinterkörper vorgesehenen, Wärme abstrahlenden Platte mit einer Wabenstruktur, jeweils zum Bewirken eines Wärmeaustausches mit dem zugeführten Kühlmittel.

7. Erwärmungs-/Kühlvorrichtung aus Keramik nach Anspruch 6, wobei

   der Sinterkörper (40) irgendein elektrisch leitfähiges, aus der aus Siliziumkarbid, Titannitrid, einer Mischung aus Aluminiumnitrid und Kohlenstoff sowie einer Mischung aus Siliziumnitrid und Molybdänsilicid bestehenden Gruppe ausgewähltes Keramikmaterial aufweist.

8. Erwärmungs-/Kühlvorrichtung aus Keramik nach einem der Ansprüche 1 bis 7, wobei

   die Wärme abstrahlende Platte aus irgendeinem Metall oder Keramikmaterial besteht.

9. Erwärmungs-/Kühlvorrichtung aus Keramik nach einem der Ansprüche 1 bis 7, wobei

   das mindestens eine Kühlungs-Durchgangsloch eine Anzahl von Durchgangslöchern (57,58,59) umfaßt und jedes der Anzahl von Durchgangslöchern eine Wabenstruktur aufweist.

10. Erwärmungs-/Kühlvorrichtung aus Keramik nach einem der vorangehenden Ansprüche, wobei

    mindestens ein Schauloch (55,56) zum Beobachten des zu erwärmenden oder zu kühlenden Gegenstands, welches mit dem mindestens einen Loch, der mindestens einen Ausnehmung oder der mindestens einen Nut bzw. Rille des Sinterkörpers (1;12;23;31;40;51;60) zur Aufnahme des zu erwärmenden oder zu kühlenden Gegenstands in Verbindung steht, in dem Sinterkörper (1;12;23;31;40;51;60) ausgebildet ist.

11. Erwärmungs-/Kühlvorrichtung aus Keramik nach Anspruch 10, wobei

    das mindestens eine Schauloch (55,56) mit einem Stoff aus einem optisch durchlässigen Keramikmaterial, einem optisch durchlässigen Glas oder einem optisch durchlässigen Harz gefüllt ist.

Revendications

1. Appareil de chauffage-refroidissement formé d'une céramique, qui comprend :
   un corps fritté (1 ; 12 ; 23 ; 31 ; 51 ; 60) ayant au moins :

   une face, au moins un trou (2, 3 ; 13-16 ; 24-27 ; 32-35 ; 52, 53), au moins une cavité (65) et au moins une gorge, chacun étant destiné à loger un objet à chauffer ou refroidir, le corps fritté (1 ; 12 ; 23 ; 31 ; 51 ; 60) comprenant une céramique isolante de l'électricité ayant une conductibilité thermique au moins égale à 10 W/m.K,
   au moins un élément de chauffage par résis-

tance (5 ; 19, 20 ; 63) utilisé comme dispositif de chauffage, enrobé dans le corps fritté (1 ; 12 ; 23 ; 31 ; 51 ; 60), et
un dispositif de refroidissement comprenant un organe d'alimentation (11 ; 50) en fluide de refroidissement placé à l'extérieur du corps fritté (1 ; 12 ; 23 ; 31 ; 51 ; 60) destiné à transmettre un fluide de refroidissement au corps fritté, et au moins un élément choisi parmi une partie de la surface du corps fritté, une partie inégale formée sur une partie d'une surface du corps fritté, au moins un trou débouchant de refroidissement (38, 39 ; 57-59 ; 62) par lequel circule le fluide de refroidissement, formé dans le corps fritté, une plaque de rayonnement (30) ayant des ailettes et placée sur le corps fritté, et une plaque de rayonnement thermique ayant une structure en nid d'abeilles, placée sur le corps fritté, chaque élément étant destiné a effectuer un échange de chaleur avec le fluide de refroidissement transmis.

2. Appareil de chauffage-refroidissement formé d'une céramique selon la revendication 1, dans lequel :

le corps fritté (1 ; 12 ; 23 ; 31 ; 51 ; 60) comprend la céramique isolante de l'électricité qui est au moins une céramique choisie dans le groupe constitué par Le nitrure d'aluminium, le carbure de silicium, le nitrure de silicium, l'oxyde d'aluminium et l'oxyde de béryllium.

3. Appareil de chauffage-refroidissement formé d'une céramique selon la revendication 1 ou 2, dans lequel :

l'élément de chauffage par résistance (5 ; 19, 20 ; 63) contient une substance quelconque choisie parmi un métal, une céramique conductrice de l'électricité et du carbone.

4. Appareil de chauffage-refroidissement formé d'une céramique selon La revendication 3, dans lequel :

l'élément de chauffage par résistance comprend au moins un métal choisi dans le groupe constitué du tungstène, du molybdène et du rhénium.

5. Appareil de chauffage-refroidissement formé d'une céramique selon la revendication 3, dans lequel :

l'élément de chauffage par résistance comporte au moins une céramique conductrice de l'électricité cnoisie dans le groupe constitué par le carbure de silicium, le nitrure de titane, le siliciure de molybdène, le borure de zirconium, le carbure de tungstène et le carbure de tantale.

6. Appareil de chauffage-refroidissement formé d'une céramique qui comprend :

un corps fritté (40) ayant au moins un élément parmi une face, au moins un trou (41, 42), au moins une cavité et au moins une gorge, destiné chacun à contenir un objet à chauffer ou refroidir, l'ensemble du corps fritté (40) comprenant une céramique conductrice de l'électricité, si bien que le corps fritté lui-même (40) forme un élément de chauffage par résistance utilisé comme dispositif de chauffage, et
un dispositif de refroidissement qui contient un organe d'alimentation en fluide de refroidissement (11 ; 50) placé à l'extérieur du corps fritté (40) pour la transmission d'un fluide de refroidissement au corps fritté, et au moins un élément choisi parmi : une partie de surface du corps fritté, une partie inégale formée sur une partie de la surface du corps fritté, au moins un trou débouchant de refroidissement (38, 39 ; 57-59 ; 62) par lequel circule le fluide de refroidissement, formé dans le corps fritté, une plaque de rayonnement thermique (30) ayant des ailettes et placée sur le corps fritté, et une plaque de rayonnement thermique ayant une structure en nid d'abeilles et placée sur le corps fritté, chaque élément étant destiné à effectuer un échange de chaleur avec le fluide de refroidissement qui est transmis.

7. Appareil ce chauffage-refroidissement formé d'une céramique selon la revendication 6, dans lequel :

le corps fritté (40) est une céramique conductrice de l'électricité quelconque choisie dans le groupe constitué par le carbure de silicium, le nitrure de titane, un mélange de nitrure d'aluminium et de carbone, et un mélange de nitrure de silicium et de siliciure de molybdène.

8. Appareil de chauffage-refroidissement formé d'une céramique selon l'une quelconque des revendications 1 à 7, dans lequel :

la plaque de rayonnement thermique comporte une substance quelconque choisie parmi un métal et une céramique.

9. Appareil de chauffage-refroidissement formé d'une céramique selon l'une quelconque des revendications 1 à 7, dans lequel :

le trou débouchant de refroidissement au moins comprend plusieurs trous débouchants (57, 58, 59), et chacun des trous débouchants

a une structure en nid d'abeilles.

10. Appareil de chauffage-refroidissement formé d'une céramique selon l'une quelconque des revendications précédentes, dans lequel :

un trou d'observation au moins (55, 56) est destiné à permettre l'observation de l'objet à chauffer ou refroidir et qui communique avec ledit trou au moins, ladite cavité au moins ou ladite gorge au moins du corps fritté (1 ; 12 ; 23 ; 31 ; 40 ; 51 ; 60) destinée à contenir l'objet à chauffer ou refroidir, est formée dans le corps fritté (1 ; 12 ; 23 ; 31 ; 40 ; 51 ; 60).

11. Appareil de chauffage-refroidissement formé d'une céramique selon la revendication 10, dans lequel :

le trou d'observation au moins (55, 56) est rempli d'une substance choisie parmi une céramique perméable optiquement, un verre perméable optiquement et une résine perméable optiquement.

FIG. 1

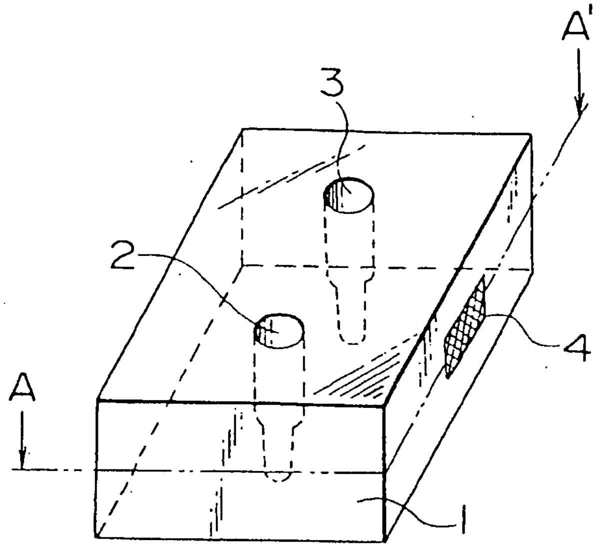

FIG. 2

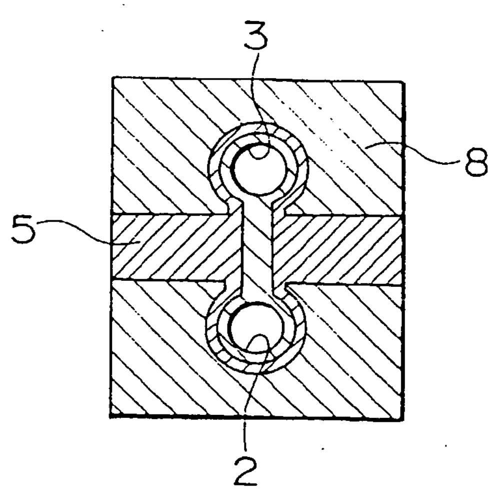

FIG. 3

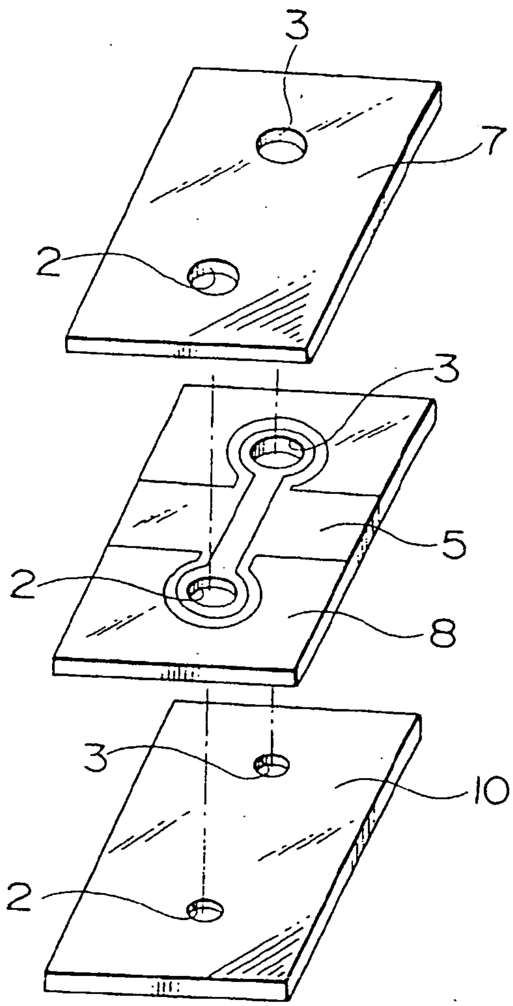

FIG. 4

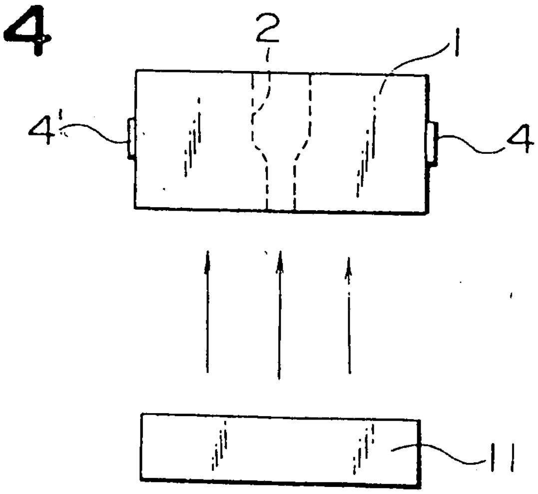
2
1
4'
4
11

FIG. 5

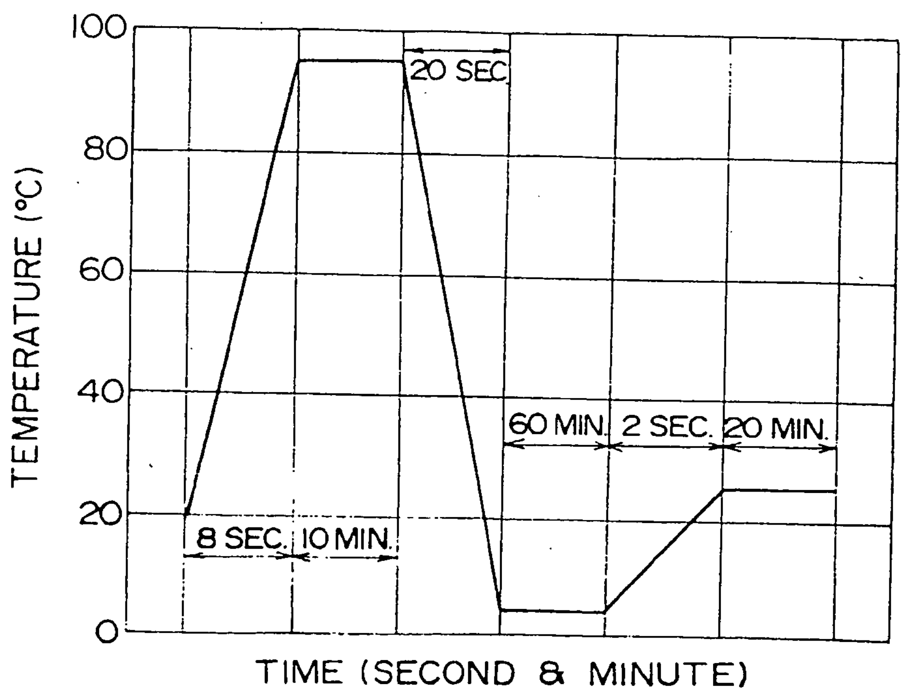
100
80
60
40
20
0
TEMPERATURE (°C)
20 SEC
60 MIN.
2 SEC.
20 MIN.
8 SEC.
10 MIN.
TIME (SECOND & MINUTE)

FIG. 6

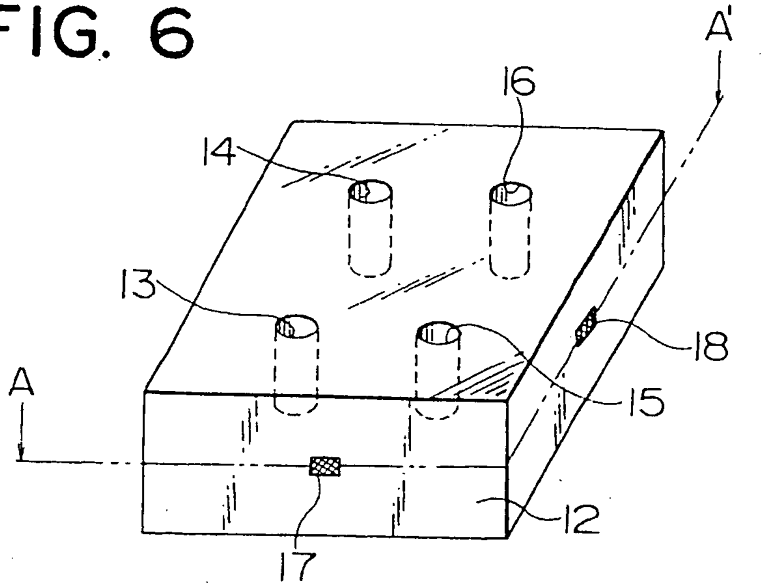

FIG. 7

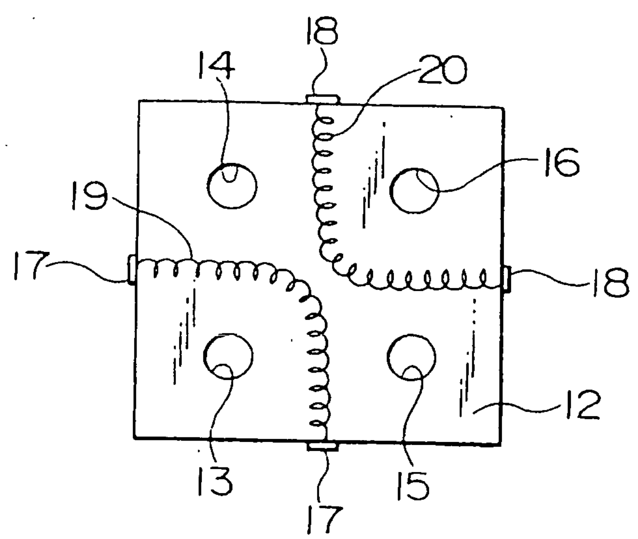

FIG. 8

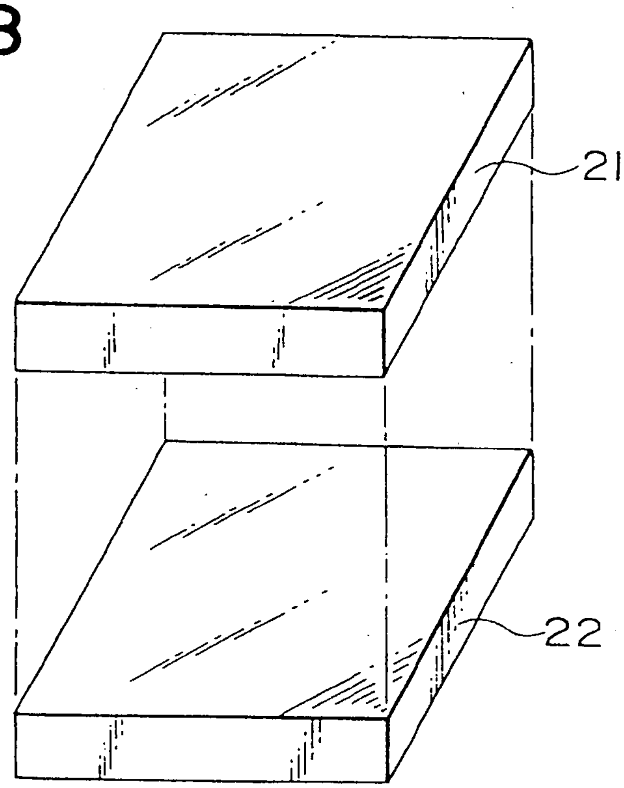

FIG. 9

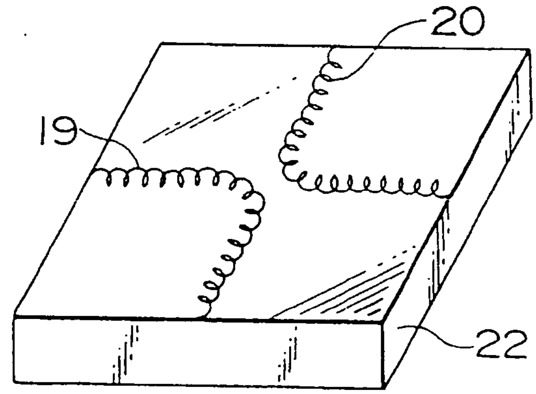

FIG. 10

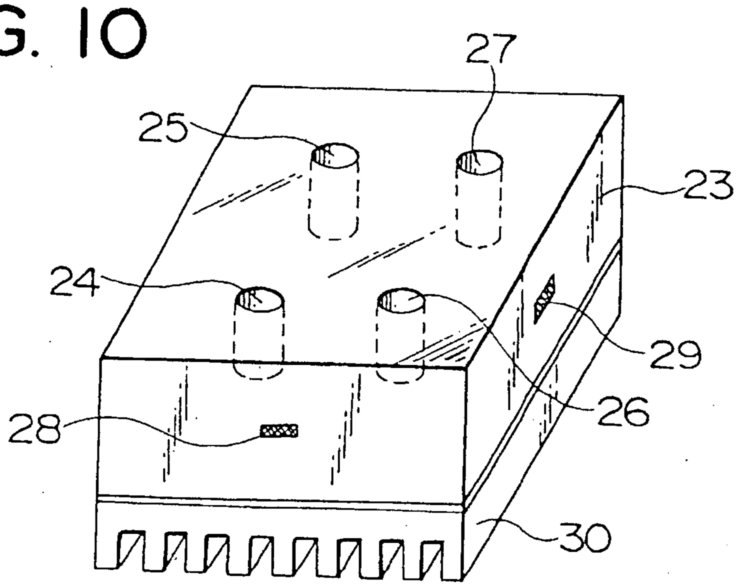

FIG. 11

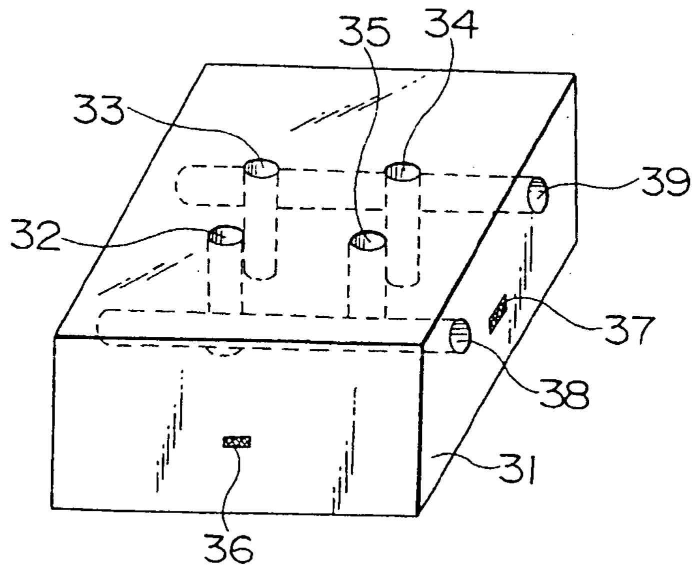

FIG. 12

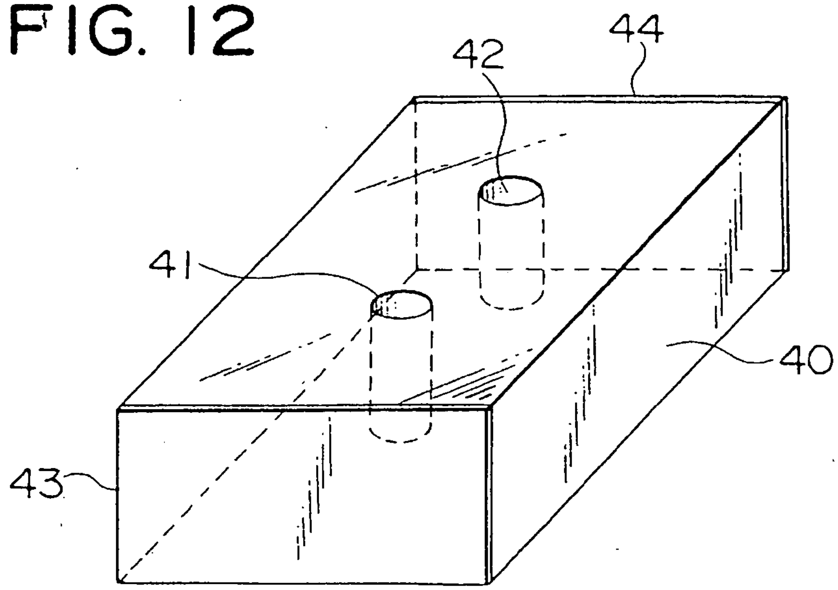

FIG. 13

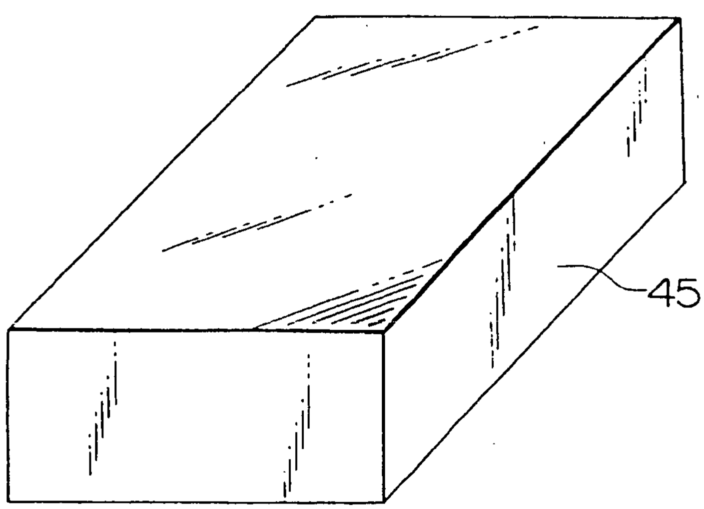

FIG. 14

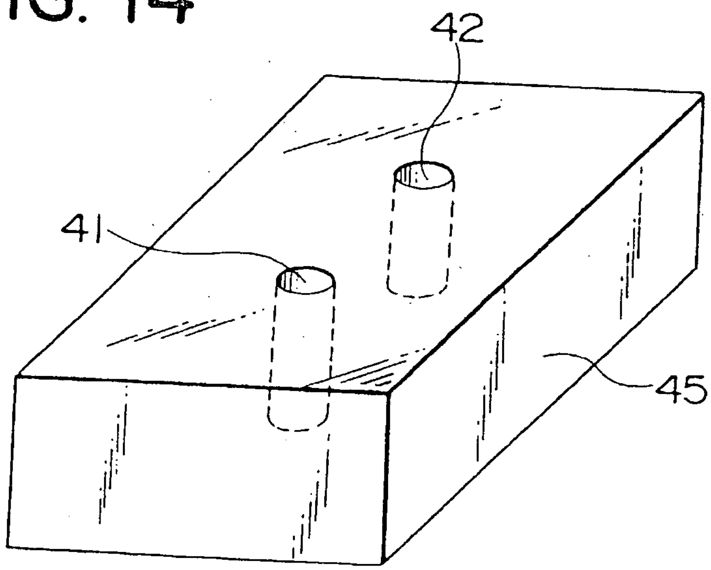

FIG. 15

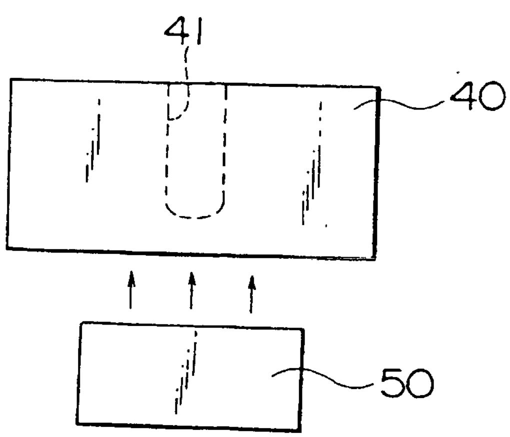

FIG. 16

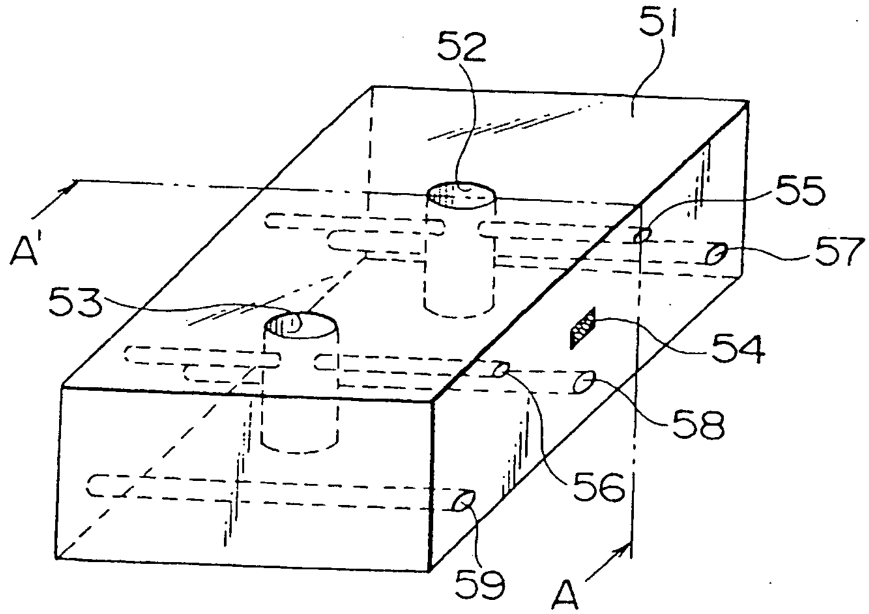

FIG. 17

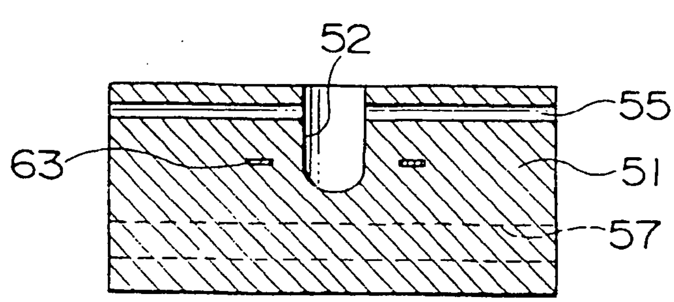

FIG. 18

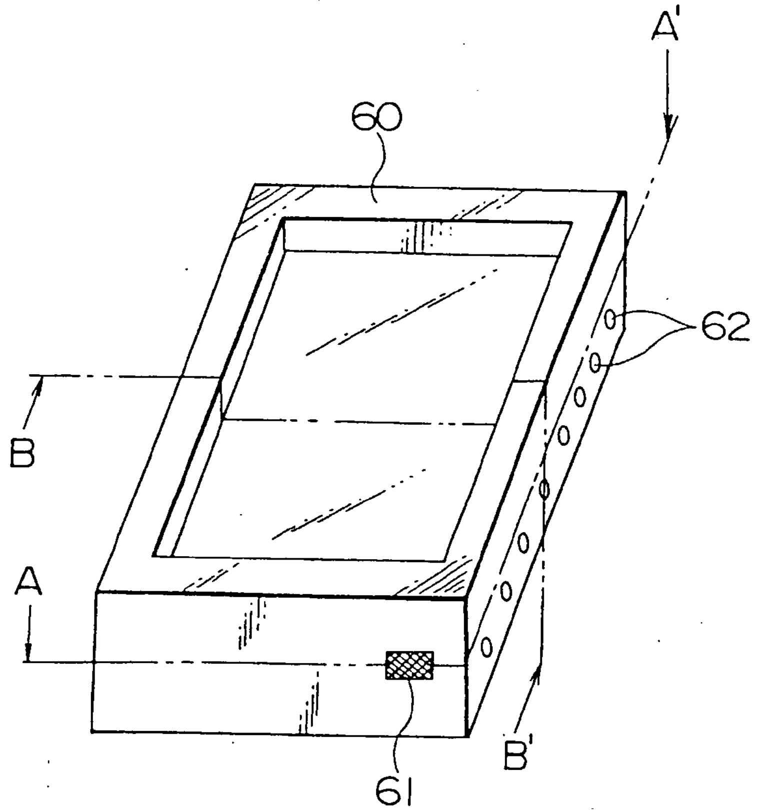

FIG. 19

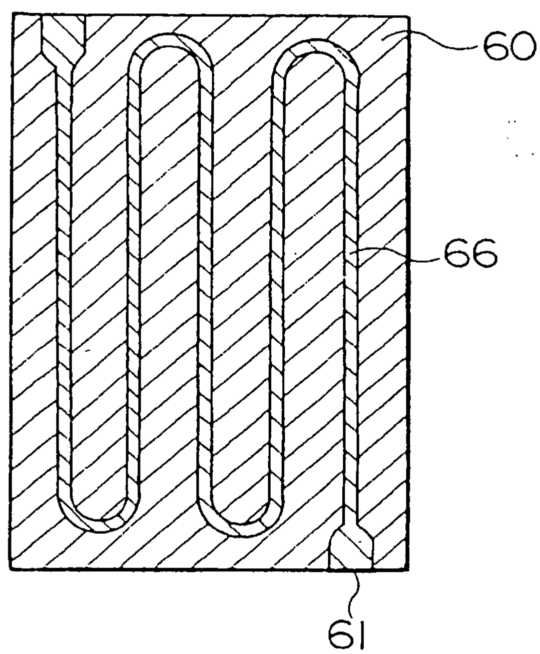

FIG. 20